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Inland Waters and Lands
Western and Northern Region

Eaux intérieures et terres
Région de l'ouest et du nord

A COMPENDIUM OF WATER QUALITY

OBJECTIVES DEVELOPMENT METHODOLOGIES

D. P. Blachford
Water Quality Branch
Western and Northern Region
Environment Canada
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1.0 INTRODUCTION

Water quality objectives are used by diverse water resource management agencies in Canada and abroad. Regardless of whether they go by the name of objectives, guidelines, standards, indicators or a number of other terms, they all serve the common function of aiding in protecting and enhancing ambient water quality. The methods by which the objectives are created, however, are varied, reflecting, among other factors, the initial need for objectives, the water quality variables of concern, the sophistication of the process and its application. Each method was selected, or evolved, to suit the purpose of the responsible agency.

This is not intended to be an all-inclusive compendium of methodologies for the development of water quality objectives. Rather, a variety of selected methods are presented and their salient features discussed. Where it was deemed useful to do so, case studies or examples are given.

An overview is presented here, in sufficient depth to allow comparison between methods and evaluation of all methods in terms of suitability for application to other river basins or lakes.

Due to the use of differing terms by the agencies, terms are defined for each method and compared with the definitions established by the Canadian Council of Resource and Environment Ministers (CCREM, 1987):

water quality objective - a numerical concentration or narrative statement which has been established to support and protect the designated uses of water at a specified site;

water quality guideline - numerical concentration or narrative statement recommended to support and maintain a designated water use;

criteria - scientific data evaluated to derive the recommended limits for water uses.

2.0 OBJECTIVES DEVELOPMENT METHODOLOGIES

Selected methodologies are presented, including description of the process and relevant examples, definition of terms and a brief summary of key aspects of each method.

2.1 BRITISH COLUMBIA

Definitions

water quality criterion - a maximum or minimum value for a physical, chemical or biological characteristic of water, biota or sediment, applicable province-wide, which must not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions. The criterion is essentially equivalent to the definition of the CCREM guideline.

water quality objective - a criterion adapted to protect the most sensitive designated water use at a specific location with an adequate degree of safety, taking local circumstances into account. It is similar to the CCREM objective definition.

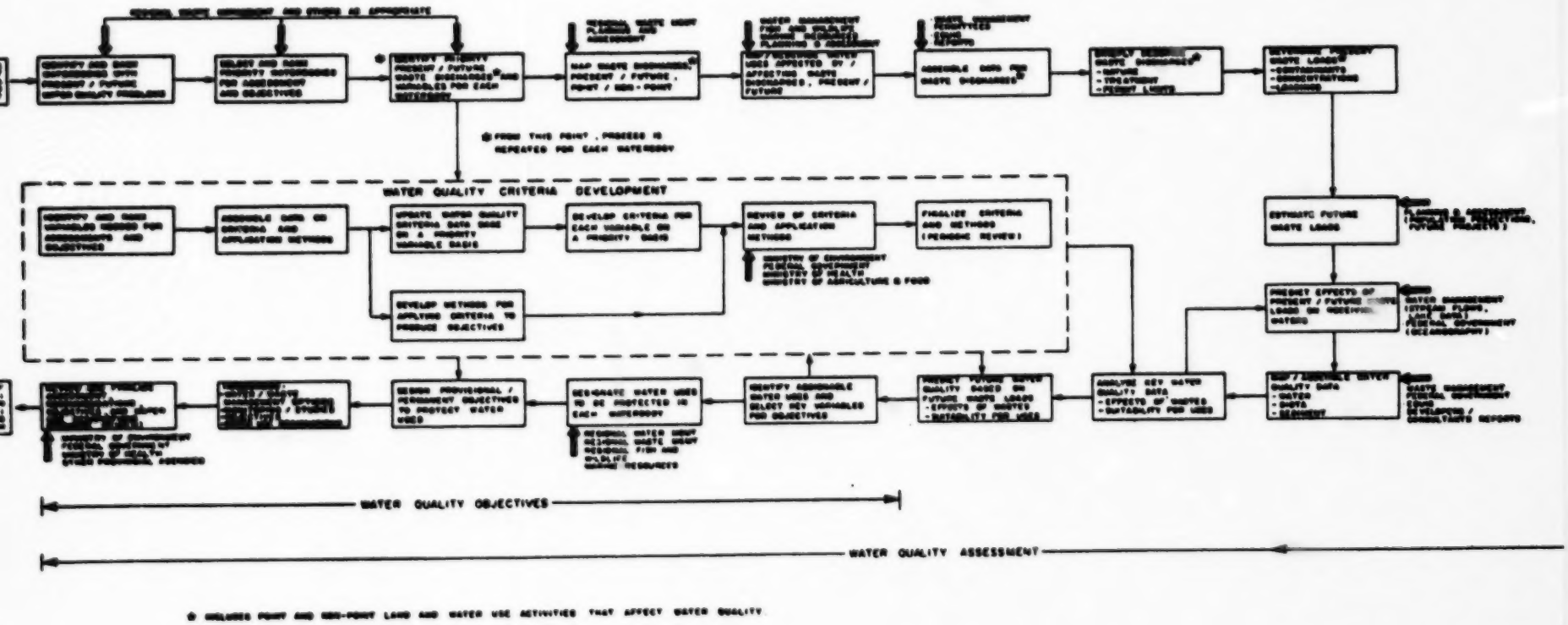
Process

The process of objectives development by the Province of British Columbia (B.C.) is best illustrated by Figure 1 (Ministry of Environment and Parks, 1986). Water quality issues are identified and ranked. Objectives are only prepared for waterbodies and for water quality characteristics which may be affected by man's present and future activities.

The preparation of a water quality assessment is an essential component of the objectives development process in B.C. Because the

FIGURE 1

WATER QUALITY ASSESSMENT , CRITERIA AND OBJECTIVES PROCESS



objectives are site-specific, they are prepared taking into consideration the local quality, water uses, waste discharges, etc., and socio-economic factors.

> For example, an assessment was prepared for the Similkameen River sub-basin by examining water quality and effluent quality data from 1965 to 1982 (Swain, 1985). A detailed technical document was compiled which formed the basis for developing objectives in areas where designated uses may be threatened.
>
> Aspects reviewed in the document included hydrology and water uses, the latter highlighting fisheries values as well as irrigation, drinking water and mining consumption uses. Waste discharges were thoroughly investigated with regard to treatment systems, impacts on river water quality and downstream use, and possible future development. Diffuse sources of pollution were also investigated. Ambient water quality data for the mainstem and tributaries were assessed for buffering capacity, characteristic levels and trends, and implications for water uses.

Province-wide water quality criteria are being developed for characteristics that are important in B.C. surface waters. These include drinking water supplies, aquatic life and wildlife, agriculture, recreation and aesthetics and industrial uses, according to the most sensitive use of a waterbody. The criteria in the scientific literature and those used by other jurisdictions are evaluated and adopted; they are, however, subject to review and revision as new knowledge becomes available. Province of the Bristish Columbia water quality criteria should be interpreted only as guidelines because they may not adequately reflect the effects of contaminants in all waterbodies (Singleton, 1986a).

> An example is presented for the development of cyanide criteria. A technical appendix was prepared (Singleton, February, 1986b) which synthesizes findings in the literature. Topics include the behaviour of cyanide in the environment (chemical groups, sources, analytical techniques), effects on water uses (eg. food processing water, algae, chronic toxicity to fish), recommended criteria and research and development needs.

> Criteria for cyanide are summarized in a separate document (Singleton, 1986a) for drinking water and aquatic life. Insufficient information was found for the other water use categories to enable recommendation of criteria. Explanation is also provided on the application of criteria, including detection levels, supporting analyses and monitoring strategies in the event of an exceedence.

Based upon the assessment and developed criteria, objectives are designed to protect the designated water uses. Provisional objectives are decided upon where site-specific information and/or criteria for a variable are inadequate. A monitoring program is specified to assess the degree of their attainment. Short-term and long-term objectives may be established where existing quality does not suit all desired uses and it is possible to improve the quality over time. The short-term objectives protect water uses until the long-term objectives can be achieved. For example;

> Provisional objectives were proposed for the Similkameen sub-basin, based upon preliminary working criteria and available data (Swain, 1985). The objectives will be provisional until more data are provided by monitoring programs and approved criteria are established for variables of concern. As an example of provisional objectives, several maximum and mean values are proposed for copper and zinc. This is to account for the different seasonal hardness regimes in the river (which affects the toxicity of metals to aquatic life), the short time periods during which values may be elevated without causing acute toxic effects to aquatic life, and the naturally occurring high values which may exceed the proposed objectives.

A final step in the objectives development process is the establishment of a monitoring program. The recommended monitoring is required to check that water quality objectives are being met, to finalize provisional objectives or to improve the accuracy of the information collected (Swain, 1985).

> The monitoring program is site- and variable-specific for the Similkameen. Characteristics for some sites are measured every second month (September to April), others are monthly or four times per year. For one site,

12 x/year is proposed for the first year and then four times per year thereafter. A site around cattle operations is to be monitored weekly for oxygen, coliforms and nutrients from April to June. Sampling frequency may be increased to observe compliance of objectives, depending on circumstances (Swain, 1985).

Key Aspects

- identification and ranking of issues
- detailed water quality assessment
- development of criteria
- establishment of objectives
- establishment of monitoring program

2.2 MANITOBA

Definitions

water quality objective - a minimum level of quality required for a specific water use. Similar to CCREM objective definition.

Process

The Province of Manitoba strives to enhance and protect the quality of surface waters in order to ensure that present and potential surface water uses are maintained. To this end, basins are classified (watershed classification) in a process through which uses are identified for bodies of water, then objectives are developed and applied to protect those uses.

Watershed classification involves evaluation of chemical, biological and physical information for the basin. For the purpose of gathering and analyzing information, the Environmental Management Division consults with provincial and federal government departments, the general public and various private agencies. Representatives from adjoining provinces or states are consulted when watersheds under

consideration are interprovincial or international. Information analyses include the characterization of uses, and the social and economic value of each.

If adequate data do not exist, water quality studies are conducted. Interim classifications are proposed for basins for which there are insufficient data and studies are not carried out (Williamson, 1983-3).

> A watershed classification proposal was put together for the Souris River watershed (Manitoba Clean Environment Commission, 1980). It included a physical description of the area, hydrology, demography, economic conditions, agriculture, fisheries, recreation, water supply sources, point sources of contamination and environmental issues of concern in the basin. The dependence of the local economy on agriculture and the need for water quality objectives to recognize its importance and ensure compatability with current and future capabilities was emphasized.

The information analysis may indicate that the best use of surface waters are the current uses. In this case, water quality objectives are recommended that maintain the present beneficial uses. If the analysis indicates the best uses are not currently attainable, then objectives are recommended which enhance the preferred uses. For water bodies with multiple uses, objectives protect the most sensitive use, also taking into consideration seasonal use protection and local water quality characteristics.

The watershed classification proposal is submitted to the Clean Environment Commission. Public hearings are held to ensure all interested and affected parties are heard. Upon acceptance of the proposal by the Minister, the Government uses the policy when dealing with water quality concerns. Changes in classification may occur due to changing land use patterns and priorities.

> The waters of the Souris River Basin have been classified according to their existing and potential uses.

> The mainstem sections and the tributaries vary in suitability for domestic consumption, fisheries and recreation, industrial use and agricultural use. The specific water quality for each case is the most limiting value of all the uses designated. The proposed classifications are based upon acceptable quality for the end use and not upon optimum social or economic benefit.

Water quality objectives are developed for substances that are known to be present and affect water uses. Specific numeric water quality objectives are developed using the best available scientific information. An example of development of objectives for the protection of aquatic-life follows (Williamson, 1986):

> Objectives are developed using the minimum data base concept published by the United States Environmental Protection Agency (1985). Principles of the method include:
>
> - The method develops objectives which are intended to avoid unacceptable adverse effects, i.e. all species are not protected in all places at all times. This contrasts with the intention of the CCREM guidelines which is to protect all forms of aquatic life in all aspects of the life cycle during indefinite exposure.
>
> - A minimum data base of laboratory toxicity information must be available, including data for acute and chronic toxicity tests conducted with various aquatic organisms.
>
> - A final acute value is calculated. This represents the concentration at which 50% of the test species in 5% of the genera are lethally affected within (usually) 96 hours.
>
> - An acute/chronic value ratio is determined.
>
> - A final chronic value is determined (final acute value divided by acute/chronic ratio). This is an estimation of the concentration of a substance that would not produce unacceptable adverse effects in all but the fifth percentile of a group of ogranisms during long term exposure. The final chronic value may be associated with other water quality variables if the toxicity is affected by changes in the other variable.

- The final chronic value may be reduced to a final residue value to account for the bioconcentration of some substances.

- A review is conducted to determine the appropriateness of the derived objectives for application in Manitoba.

In cases where there is insufficient available data for the formulation of an objective, a value is estimated. Objectives take the form of narrative statements where specific numeric objectives cannot reasonably be developed.

i.e." Free from materials that produce colour...in such a degree as to...impair any beneficial use."

The result of the objectives derivation process is a set of objectives specific for each use. For example, the iron objectives differ for domestic consumption (0.3 mg/L), cold water aquatic life (1.0 mg/L) and irrigation (5.0 mg/L). The total mercury objectives differ for domestic consumption (0.001 mg/L), cold water aquatic life (0.00057 ug/L) and livestock use (0.003 mg/L)(Williamson, 1983-2).

The objectives are under ongoing revision as new data become available. For example, the mercury objective for cold water aquatic life has been revised to 0.006 mg/L for acid-soluble mercury (Williamson, 1986; Williamson, 1986-12).

Once formulated, the objectives are applied to specific streams, lakes or entire watersheds to protect uses identified in the watershed classification procedure. Objectives are applied on a site specific basis within watersheds for which a classification proposal has not been adopted as policy.

Application of objectives to the Souris River Basin illustrates the effects of one classification. The colour objective appropriate for the Coulter region is 15JTU, whereas Sharpe Lake and Stoney Creek, with different classifications, have colour objectives of 30 and 100JTU respectively. Similarily, the objectives for faecal coliforms (100, 200, 400/100 ml) differ at the same sites reflecting different degrees of use protection. (Manitoba Clean Environment Commission, 1980)

Key Aspects

- objectives are basin and/or reach specific
- aquatic life are not fully protected
- there is no associated monitoring program
- Manitoba does not currently have the technology to measure many forms of the specified objectives

2.3 PRAIRIE PROVINCES WATER BOARD

Definitions

maximum acceptable concentration - describes a water quality condition that should not be exceeded to ensure the protection of downstream water uses.

water quality indicators - describe the chemical concentration or biological or physical effect that should be investigated if exceeded in the water as it crosses an interprovincial boundary. Indicators are comparable to the CCREM definition of objectives.

Process

Water quality indicators have been developed and are being reviewed for all Prairie Provinces Water Board (PPWB) sites to aid in site-specific water quality management. Development of the indicators includes consideration of local biological, hydrological, geochemical and demographic characteristics. A two-level approach is used to develop short and long term indicators (Dunn, 1985).

An initial step in the process is the identification of water uses by the downstream jurisdiction and Canada, and the identification of variables which affect those uses. Next is an evaluation of the water quality and quantity data bases. Sampling times are compared with flows

to determine the flow range for which quality is characterized. variables are summarized statistically (range, mean, median, percentiles, standard deviation, variance, skewness) to aid in formulation of the indicators. All variables are tested for seasonality to establish the need for separate ice-cover and open water indicators or a combined data set for an annual indicator. Maximum acceptable concentrations are derived from current water quality literature.

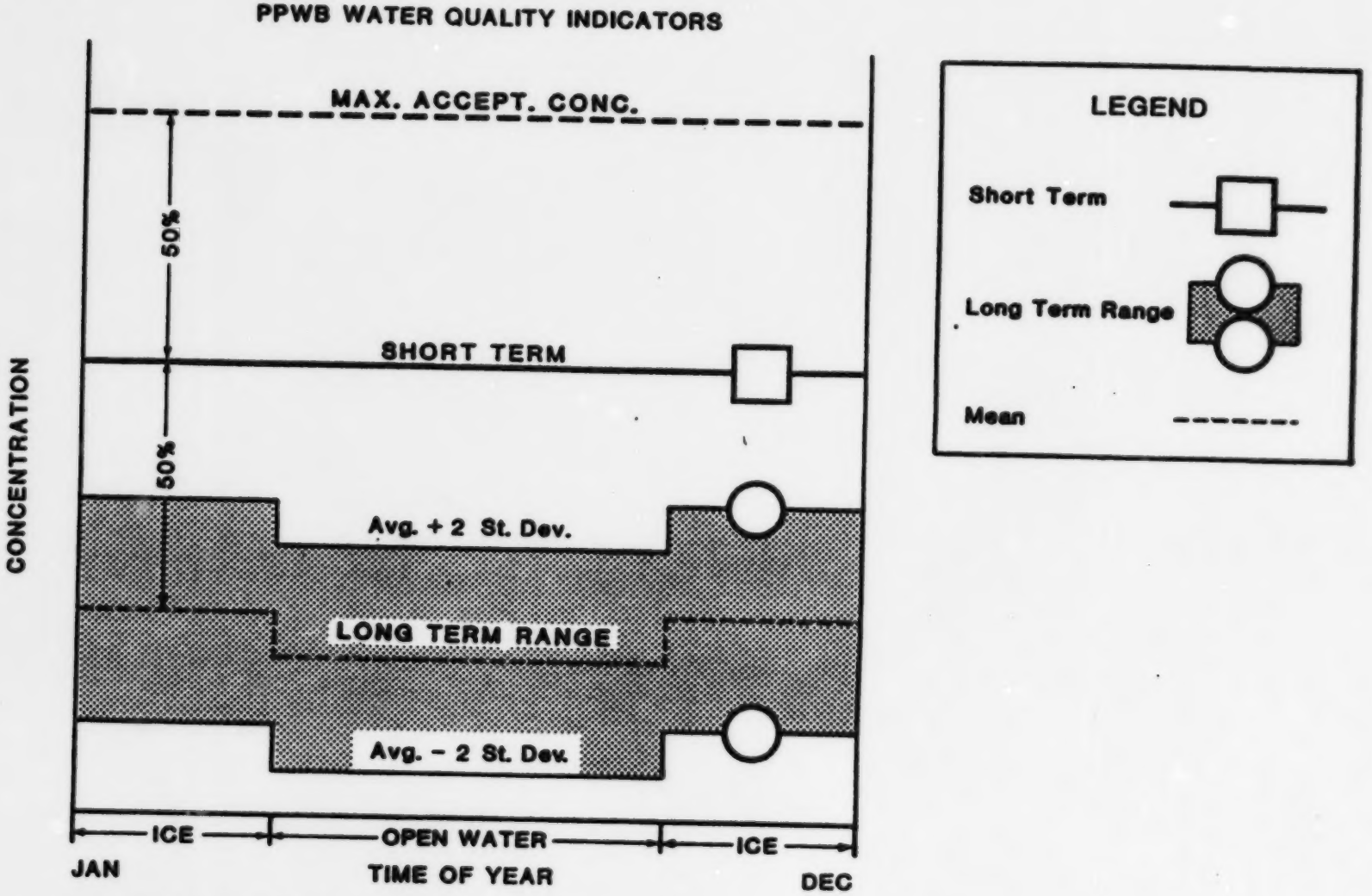
Short term indicators are calculated as a value halfway between the mean annual concentration and the maximum acceptable concentration (Figure 2). The values are not seasonally differentiated. Concerns related to acute toxicity are addressed by consideration of the maximum acceptable concentration.

Long term indicators are calculated as the range of values $\pm$ two standard deviations from the seasonal (open water and ice-cover) or the annual (for variables not exhibiting seasonality) mean concentration (Figure 2; Dunn 1985). The long term indicators are developed to show trends which may occur over a long period of time. They are used to compare the annual and seasonal means of data collected in the future with those of historical data.

As well as the short and long term indicators, general water quality indicators are also formulated. These are narrative statements that summarize transboundary water quality conditions acceptable to the PPWB.

> Indicators have been proposed for the Alberta-Saskatchewan border crossing of the Beaver River. Background work included characterization of physical (physiography, hydrology) and cultural (land use, demography, economy) features. Water uses were identified as domestic and municipal consumption, protection of aquatic life, propagation and maintenance of wildlife, industrial consumption, irrigation and non-contact recreation. Variables most relevant to each use were identified so that variable-specific indicators could be developed according to the most sensitive use for each variable.

Figure 2. Diagrammatic Description of the Two-Level Approach



NB. Average Level is based on Recorded Seasonal Data
1974 - 1982 inclusive.

All general water quality indicators apply to the Beaver River crossing, such as: "Water crossing the interprovincial boundary should be free from substances in concentrations or combinations which are toxic or may be harmful to human, animal or aquatic life." Specific indicators are proposed for a wide variety of variables. Indicators for dissolved boron are illustrated in Table 1.

Table 1. Indicators and Calculations for Boron

Most sensitive use: irrigation

Maximum acceptable concentration: 2.0 mg/L

Short term indicator: 1.1 mg/L
: $\frac{\text{maximum acceptable concentration + highest seasonal mean}}{2}$

Long term indicator: 0.06 - 0.23 mg/L, ice-cover
: 0.03 - 0.20 mg/L, open water
: seasonal mean $\pm$ 2 standard deviations

Key Aspects

- process is based upon site-specific water quality data
- long term indicators account for seasonality
- detection of long term trends
- acute toxicities are considered
- protection of the most sensitive use.

2.4 ALBERTA, SASKATCHEWAN

Definitions

water quality objective - similar to the CCREM definition of objective. However, the provinces recommend that they be regarded as CCREM-style guidelines.

Process

Objectives for Alberta and Saskatchewan are based upon criteria developed by U.S. Environmental Protection Agency in the 1970's, which have been adopted to be applicable to the region. The objectives apply province-wide.

The water quality management objectives of Saskatchewan are "to conserve water and to protect, maintain and improve its quality for the protection of public health and within economic limits, for the following purposes:

a) preservation and protection of water supplies;
b) encouragement of economic development;
c) preservation of aesthetic values; and
d) preservation of fish and wildlife"
(Saskatchewan Environment, 1983).

The objectives are used in the assessment of the quality of water and municipal and industrial wastewater effluents. They are used to determine the type and degree of treatment required to maintain suitable surface water quality. General, narrative objectives and specific numeric objectives apply to all waters receiving effluent discharges.

Alberta and Saskatchewan are reviewing their current objectives. Saskatchewan is formulating a set of use-specific objectives based upon the CCREM guidelines. A few general and some specific (e.g., D.O., turbidity) objectives are being developed to apply to all surface waters; all other objectives are use-specific (exclusive of municipal and industrial uses). Alberta is considering updating its objectives pending further study of the CCREM guidelines and their application.

Key Aspects

- objectives are being updated
- easy to apply
- no site/basin or use specificity.

2.5 POPLAR RIVER

Definitions

water quality criteria - the scientific information used to assess the effects of a variable on a particular water use. Similar to CCREM definition of criteria.

water quality objective - the level of a variable which is determined as acceptable for a particular water use. Similar to CCREM definition of objective.

Process

In the 1970's, Saskatchewan Power Corporation commenced plans to build a coal-fired, electric power generating plant in the Poplar River Basin. Cooling water was to be provided by placing a dam on the East Poplar River. Concern over the water quality implications of the project prompted Canada and the United States to issue a reference to the International Joint Commission (IJC) regarding water quality in the basin. The IJC established the International Poplar River Water Quality Board (IPRWQB) in 1977. The Board was requested to carry out a comprehensive study of present water quality and potential water quality effects of the project. One of the Board's tasks involved developing and recommending water quality objectives to be met at the international boundary (IPRWQB, 1979).

The Board initially developed use-specific objectives for municipal and domestic potable water supply, agricultural use, indigenous biota requirements and recreational and aesthetic considerations. Values were derived by evaluating the best available scientific information for each water use and parameter, and using application factors and professional judgement to ensure protection of the Poplar River basin waters. The objectives are applicable to all locations within the

basin. The values should not be used as absolute limits of water quality but with local considerations, a supporting monitoring program and an understanding of the derivation of the values. The objectives are expected to give an adequate degree of protective assurance for water users until better scientific information becomes available (IPRWQB, 1979).

Multi-purpose water quality objectives were then compiled. These objectives were developed by the IPRWQB and proposed to the IJC. They represent the most sensitive of the uses in the basin, and provide protection to present and foreseeable uses downstream at the point of use. Variables for which the natural water quality was higher than the scientifically-based limit had the objective altered to the level of the natural water quality. Adherence to the water quality objectives will protect the life systems the waters support and the designated water uses. Development of the objectives took into account the cumulative effect on any impoundments that may be put in place in downstream portions of the basin.

Water quality studies indicated that boron and total dissolved solids (TDS) were the variables most likely to be affected by the project. They are naturally present in the Poplar River in relatively high concentrations. Special objectives, proposed by the I.J.C. to Canada and the United States, were formulated for boron and TDS as increased concentrations could have deleterious effects on the production of some irrigated crops.

The objectives for boron are:

1) the long term (5 year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 - September 30) should not be caused to exceed 2.5 mg/L;
2) the short term (any three consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period should not be caused to exceed 3.5 mg/L.

Irrigation is the use most sensitive to boron in water. Impairment to irrigated crops depends upon crop type, amount of water applied, previous accumulation and soil type. The most sensitive irrigated crop in the basin is barley. For example, barley yields are reduced by 15% at boron concentrations of 3.0 mg/L and by 40% at concentrations of 8.0 mg/L. The objectives, therefore, do not protect barley, but its importance is considered to be small in relation to the total irrigated area in the basin. The principal irrigated crop is alfalfa and its production is not impaired by 5.0 mg/L boron.

The objectives for TDS are:

1) the long term (five year) arithmetic mean of the monthly flow-weighted means during the irrigation period (May 1 - September 30) should not be caused to exceed 1,000 mg/L;
2) the short term (any three consecutive months) arithmetic mean of the monthly flow-weighted means during the irrigation period should not be caused to exceed 1,500 mg/L.

Crop impairment due to elevated TDS levels is dependent upon the amount of water applied, soil types, soil treatment, crop type and the sodium adsorption ratio. The literature recommends acceptable levels ranging from 500 - 5,000 mg/L. Experience in North America, however, has shown that some irrigation operations using waters with TDS levels below 1,000 mg/L have failed, and others using waters with TDS levels above 1,500 mg/L have been successful.

The objectives are expected to provide adequate protection for the irrigation uses of the basin as long as the water is applied in recommended amounts.

An annual review and interpretation of the data is carried out by the Board. The technical monitoring schedule is also reviewed annually. There is a mandatory review of the objectives every five years.

<u>Key Aspects</u>

- protection of most sensitive use.
- site-specific objectives formulated for variables of concern.
- ongoing observation of objectives compliance and effectiveness.

2.6 INTERNATIONAL RED RIVER POLLUTION BOARD

Definitions

water quality objectives - a tool for effecting water quality management; a limit or narrative statement which has been negotiated to support and protect the designated uses of water. Similar to the CCREM definition of objectives.

alert levels - concentrations or narrative statements based on criteria, existing quality and other factors, which have been derived to trigger investigative action by the Board into the potential risks to water uses caused by contravention of these levels.

Process

The International Red River Pollution Board (IRRPB) was established by the International Joint Commission (IJC) in 1964 to investigate and report on the extent of pollution of the waters of the Red River (IRRPB, 1967). Field investigations carried out in 1965-66 highlighted a series of variables of concern. Based on the investigations, the Board recommended the adoption of water quality objectives for fecal coliforms, chloride, sulphate, total dissolved solids and dissolved oxygen. The objectives, developed for the waters of the Red River crossing the international boundary, were approved by the Canadian and United States governments in 1969.

A more extensive list of water quality objectives was proposed by the Board to the IJC in 1981. The purpose of these objectives was to restore and maintain the chemical, physical and biological integrity of the Red River. The objectives were developed to protect the most sensitive use of the water, were minimum levels and did not preclude the establishment of more stringent requirements, and did not apply where natural phenomena prevent the attainment of some of the objectives (IRRPB, 1982). The proposed objective was derived from the more restrictive state standard or provincial objective. In some cases the

values were the same, in others a compromise was reached. To date, the IJC has not granted approval for the official use of these objectives. The Board has, however, taken the liberty of reporting upon observed exceedences of the proposed objectives (IRRPB, 1983, 1984a).

In 1984, the concept of alert levels was presented to the IJC. Alert levels are intended to trigger investigative action by the Board into the potential risks to water uses caused by contravention of the levels. They complement water quality objectives. The objectives continue to be the primary means of identifying water quality issues and require the commitment of governments. Alert levels are monitoring tools which indicate a potential concern to be studied by the Board in terms of magnitude, implications to water uses and possible solutions. The alert levels provide the Board with information it requires to rationalize its requests to the IJC for revisions or additions to the current water quality objectives.

An alert level may be upgraded to objective status. This may occur if the Board recommends water quality objectives to the IJC if it feels it requires the efforts of the IJC and the commitments of governments to resolve a water quality issue.

When objectives are exceeded, the Board recommends to the IJC a course of action to involve governments in taking mitigative measures. Exceedence of an alert level does not mean that there has been a contravention of a commitment made by governments, but it does signal a potential risk to water uses. In either case, the Board assesses the risk implications (IRRPB, 1984b).

Water quality alert levels were approved by the Board in 1986. The levels were reviewed and tested in 1986 by the Water Quality Objectives Task Force. The Board reports exceedences of alert levels and objectives and identifies potential concerns in its annual report to the IJC. The only modifications made to the alert levels since their

approval have been to eliminate turbidity and colour due to repeated natural exceedences (IRRPB, 1987).

Key Aspects

- objectives have governments commitment
- objectives are not site-specific
- alert levels signal the need for investigative action

2.7 ONTARIO

Definitions

water quality objectives - a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water. They are similar to CCREM guideline definitions.

water quality criteria - scientific data evaluated in the formulation of objectives. They are similar to CCREM criteria definition.

The goal of the objectives is to ensure that surface waters of the province are of a quality which is satisfactory for aquatic life and recreation (Ontario Ministry of the Environment, 1984). Waters of the designated quality will be suitable for most other beneficial uses. The objectives apply province-wide. The objectives for aquatic life protection are designed to protect all forms of aquatic life and all aspects of aquatic life cycles. Objectives for the protection of recreational water uses are based on public health and aesthetic considerations. The objectives are based on data produced by exposing healthy, stress-free organisms to one variable (water quality parameter) at a time. They do not account for additive effects of more than one variable (synergistic effects) or for other environmental stress.

Each objective should ideally be established with data derived from chronic toxicity tests to ensure aquatic life protection. However, much of the current data is limited to a few species and acute toxicity tests (Ontario Ministry of the Environment, 1979). Therefore, objectives are derived from acute test data and application factors. Short term toxicity test results are usually expressed as median lethal concentrations (LC_{50}, the concentration of test material that causes death to 50% of test organisms within a given time period). An application factor is the ratio of the maximum concentration having no negative effect to the 96-hour concentration. The application factors commonly used are:

- concentrations of materials that are nonpersistent should not exceed 0.1 of the 96-hour LC_{50}. The 24-hour average of the concentration should not exceed 0.05 of the LC_{50}.

- concentrations of materials that are persistent should not exceed 0.05 of the 96-hour LC_{50}. The 24-hour average concentration should not exceed 0.01 of the 96-hour LC_{50}.

The scientific data base is constantly changing and more chronic data are becoming available. Objectives will be reviewed on an ongoing basis and revised as necessary. Objectives are also being developed for new substances as the need arises.

> Due to the widespread occurrence of the toxic properties of chlorophenols (CP's), there was a need to establish objectives for the protection of aquatic ecosystems (McKee et al., 1984). The objectives are designed to protect the most sensitive use of the aquatic ecosystem against CP contamination. These procedures were followed in the development process:
> - the lowest species - specific mean LC_{50}value for the most toxic CP isomer in each group (mono$^-$, di$^-$, tri$^-$, tetra$^-$, penta$^-$) was selected for the acute toxicity data base;
> - persistence of each CP group was identified;
> - an application factor was applied to the lowest species-specific mean LC_{50};

- the lowest fish flesh tainting concentration was lowered to provide protection from tainting;
- the more protective of the concentrations or the tainting values was used for a final criteria for each group, and compared with chronic data to ensure protection.

The recommended objectives represent maximum concentrations in surface waters that should not create any acute or chronic response in the most sensitive aquatic organisms, and should not cause any impairment of flavour in fish flesh.

2.8 OTTAWA RIVER

Definition

water quality objectives - Similar to the CCREM definition.

Process

Water quality objectives were established for selected variables in the Ottawa River as part of the work being carried out by Canada, Quebec and Ontario on the water quality of the interjurisdictional sector of the river. The Coordinating Committee for Water Quality (1985) recommended objectives that are designed to protect drinking water supplies, aquatic life, contact recreation, aesthetics and sport fisheries.

Numeric objectives were proposed for variables whose presence in the river should be controlled to protect the identified uses. The objectives are based on values that were available at the time, including those of Health and Welfare Canada (1978), Environment Canada (1983), U.S. EPA (1980), World Health Organization (1984) and Ontario Ministry of the Environment (1984). Some values are directly adopted Ontario objectives. Others, such as dissolved oxygen, are modified to the requirements of the local fish populations. Some analyses were carried out during the objectives development exercise to determine the need for objectives for certain variables. For all variables, the proposed

objectives were compared to monitoring data to determine potential exceedences.

It is anticipated that the CCREM guidelines and the revised Health and Welfare Canada drinking water quality guidelines will form the basis for objectives needed for aquatic life and drinking water protection, and for expansion and revision of the current objectives. This task is expected to be underway in 1988.

Key Aspects

- estimated objectives to be improved when new information is available.

2.9 GREAT LAKES SCIENCE ADVISORY BOARD

Definitions

water quality objective - describes a minimum quality of water which will provide for and protect any designated use. Similar to CCREM guideline definition.

procedural objectives - an objective developed for local situations where an inadequate scientific data base exists to permit establishment of numeric objectives for nonpersistent toxic substances and complex wastes. Specific bioassay tests are conducted on the most sensitive local species, and an application factor applied to the toxicity data.

Process

In 1972, Canada and the United States signed the Great Lakes Water Quality Agreement confirming their obligation to meet the Boundary Waters Treaty of 1909 that "boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other". General and specific objectives were established and included as an Annex to the Agreement.

It was the responsibility initially of the Water Quality Objectives Subcommittee and the Scientific Basis for Water Quality Criteria Committee to formulate new or modify existing water quality objectives. The philosophy of protection of the most sensitive use was employed. In most cases, objectives were established to protect aquatic life or their consumers. Protection of public water supply is employed next in frequency. Aesthetics and/or recreational uses are most sensitive for only a few variables. Each objective alone provides protection from some effects, however, it is not known whether uses are protected when two or more minimum conditions occur simultaneously (IJC, 1974).

During the years following the 1972 Agreement, there was growing recognition that the objectives may not protect the ecosystem from the full impacts of human activity. The objectives are for single variables only, are dependent on establishing a link between the measurability of many toxic substances and actual regulations, and do not reflect the combined effects of substances. Most objectives are based on short term, acute, chemical, physical or biological impacts under laboratory conditions and do not reflect the synergistic, long term, chronic and in-situ conditions which actually occur (IJC, 1986). The need for alternate measures of ecosystem quality emerged.

Since the 1978 Agreement, the Aquatic Ecosystem Objectives Committee (AEOC) has had the responsibility of keeping the objectives up to date. The AEOC has recommended the adoption of new objectives, the revision of existing objectives and has promoted the use of biological indicators as measures of ecosystem health.

Numeric objectives are developed by extensive review of considerations including: physical-chemical properties, occurrence in the Great Lakes, accumulation in and lethality to biota, degradation and persistence, water quality effects on lethality, and human health effects. These are evaluated in the Great Lakes context and an objective is recommended.

Invertebrates and fishes have the most sensitive responses to lindane in the aquatic ecosystem. Fish show lethal effects at 1 - 2 ug/L while invertebrates demonstrate sublethal effects with chronic exposures at the same levels. Applying the 0.2 safety factor used for persistent toxic substances in the Great Lakes indicates a level of 0.1 ug/L. A more protective level is required, however, as this level is too close to fish lethality data, is above the safe level estimated in a field situation and is above the sub-lethal effect level found for a relevant invertebrate. It is recommended (IJC, 1984) that the existing objective (0.01 ug/L) be changed to 0.02 ug/L, derived from the lowest invertebrate 96-hour LC_{50} (1 ug/L), a 0.081 application factor for sensitive invertebrates and a safety factor of 0.2 used with persistent toxic substances (IJC, 1975). The objective for edible portions of fish (0.3 ug/g) should remain unchanged.

The recommended objective for un-ionized ammonia is 0.03 mg NH_3/L, as this is the highest no-effect concentration for the most sensitive response of aquatic biota. This level also protects raw water supplies for drinking water. Aquatic life is protected from short term exposure to ammonia by a level derived from a water pH and temperature calculation; this estimates the lethal threshold concentration for rainbow trout for 96 hours of exposure (IJC, 1975). The concentrations are based on demonstrations that fish can tolerate short term exposure to potentially lethal levels with no apparent detrimental effect.

The AEOC, realizing the limitations of the traditional chemical objectives approach, and to fully account for potential adverse effects on biotic communities, placed increasing emphasis on using <u>in situ</u> biological components of the ecosystem to evaluate the biological integrity of the waters of the Great Lakes Basin. The AEOC recommends the maintenance or restoration, to the extent possible, of conditions that the Great Lakes are known to be capable of sustaining. To implement this philosophy, an objective for a healthy Lake Superior ecosystem is proposed. This would complement the numeric (chemical) objectives.

The proposed ecosystem objective is:

"Lake Superior should be maintained as a balanced and stable oligotrophic ecosystem with the lake trout as top aquatic predator of a cold-water community.

Note: In order to determine whether this condition exists, the following criteria should be met:

1) the lake trout productivity should be greater than 0.38 kg/ha as determined using mortality rates;

2) there should be a stable number of recognizable, self-reproducing stocks;

3) the annual harvest of lake trout should not exceed 0.24 kg/ha;

4) the harvest of lake trout should be free from contaminants at levels which adversely affect the trout themselves or the quality of the harvested product."

The lake trout was chosen as an appropriate organism to act as a surrogate for the whole community of organisms in Lake Superior. It integrates, through terminal predation, much of the biological structure of the oligotrophic lake system (Ryder and Edwards, 1985). Criteria for an effective indicator, which the trout meet, include:

- having a broad distribution in the system;
- being easily collected and measured;
- being indigenous and maintaining itself by natural reproduction;
- interacting with much of the ecosystem;
- having quantified information on the species;
- exhibiting responses to stress;
- indicating aspects of ecosystem quality other than those represented by presently accepted parameters (Aquatic Ecosystem Objective Comm., 1986)

While the lake trout is recommended as the initial indicator of ecosystem quality, it is recognized that evaluation of the status of only one organism may not be adequate to give a complete indication of the health of the Great Lakes (Ryder and Edwards, 1985). The amphipod Pontoporeia hoyi is suggested as a complementary indicator to the lake trout. The amphipod provides information on the quality of benthic environments, whereas trout provides information primarily on limnetic conditions; P. hoyi indicates conditions near the bottom of the food chain; trout indicate conditions for predators near the top of the food chain. P. hoyi is sedentary and therefore reflects local environmental quality; trout reflects conditions over the broad areas where the fish range (Robertson, 1987). It is thus recommended that the ecosystem objective be amended to include:

"5) within the limits of natural variability, the abundance of P. hoyi in the entire lake and in all major subregions should be maintained at present levels."

Key Aspects

- traditional chemical objectives in water are complemented by chemical objectives in tissue.
- most sensitive use is protected.
- biological components are used as indicators of ecosystem health.
- requires extensive background biological information.
- requires intensive monitoring efforts and high level of expertise.

2.10 SAINT JOHN RIVER BASIN

Definitions

safe level - a concentration beyond which increasing levels lead to slow, sublethal effects, gradually reaching the point of lethality as the time element and concentration increase.

acute limit - a concentration corresponding to EPA's "final acute value". It is determined by selecting the lesser of the lowest 96-hour LC_{50} available for fish (or invertebrates) or the result of applying a division constant to the geometric mean of 96-hour LC_{50}'s.

limit to protect swimmers - a concentration which will protect swimmers from adverse reaction.

Process

Water quality objectives for the St. John River Basin were developed to protect the "fishable - swimmable" use (Canada-U.S. Committee, 1975). The objectives have been compiled as a combination of the objectives developed separately for fisheries and contact recreation uses. The objectives apply to the international portion of the mainstem, and to tributaries at international crossings and at their confluence with the international portion of the river.

Two separate levels of quality were developed to support fisheries. Previous versions of the objectives related the levels to the degree of protection afforded to aquatic life. These have been modified to reflect the inability to infer use impairment based upon toxicity data and grab sample data. Consequently, the most recent objectives (Int. Techn. Adv. Sub., 1980) relate to the interpretation of monitoring data at the grab sample and annual average levels, with dominant consideration given to provision of an adequate degree of safety for all forms of aquatic life. Objectives are established with the understanding that there is no zero-effect level, variables exert varying effects depending on physiochemical characteristics of the environment, and the maintenance of ambient conditions is desirable where they are more protective than objectives. The effects of interactions between variables (joint toxicity) are not incorporated in the objectives formulation process.

One level of protection to support fisheries is an objective

representing a long term management goal. This value should be compared to annual or seasonal averages of monitoring data. The second level of fisheries protection is an alert level. This level (based upon old U.S. EPA old criteria) is to be used as a point with which to compare the analyses of single grab samples to identify immediate problems.

Only one level of protection is established for contact recreation. The recommended limits are based upon old U.S. EPA drinking water criteria, modified to account for the lesser quantity of water likely to be ingested by swimmers and the seasonal nature of the water use.

The St. John River objectives are accompanied by an explanation of the significance of not meeting the recommended levels. Generally, exceedence of objectives indicates a threat to aquatic life or to recreational water uses. In the case of contact recreation, the area should be closed to swimming. In the case of aquatic life, death of a proportion of the fish population or a chronic effect occurs, depending on the variable and the amount of exceedence.

Objectives have been developed for variables recommended by the Water Quality and Sampling Subcommittee (1979). Objectives for variables are added or deleted in consideration of new developments, inapplicability to the fishable-swimmable use, or because their levels are unlikely to be affected by human activity.

The recommended objectives are compared to Canadian and American monitoring data from all sites in the basin. This is to ensure that objectives are not established which cannot be attained analytically or for reasons of background water quality (Int. Techn. Adv. Comm., 1980).

The following is the rationale for the mercury objective:

"The recommended limit to protect swimmers is 0.002 mg/L methylmercury. Epidemiological evidence shows that the lowest whole-blood concentration of methylmercury associated with toxicity is 0.2 ug/g. This value corresponds to a continuous exposure of 300 ug/70 kg body weight/day. If a safety factor of 10 is used, an adult could safely ingest 0.03 mg of mercury per day and a child proportionally less if the safety factor of 10 is to be maintained. Additional protection may be provided if all of the mercury is not in the highly toxic methyl or dimethyl form. Because certain microorganisms may convert inorganic and organic forms to the methylated forms, any mercury in the environment is a hazard.

Background levels of mercury in the Saint John River are normally 0.0001 mg/L or less, although occasional readings of 0.002 or 0.003 mg/L are on record. The credibility of some of the data on record is in doubt, and the need for routine low level mercury measurements continues to press the state of the art. In the past, the U.S. EPA has consistently maintained that 0.00005 mg/L mercury is the criterion necessary to protect aquatic life. A revision to this criterion was suggested in the October 1, 1979, issue of the Federal Register. Following the rationale for this revision, the recommended acute limit is 0.0032 mg/L inorganic mercury or 0.0088 mg/L methylmercury. The recommended safe level is 0.000064 mg/L inorganic mercury or 0.000016 mg/L methylmercury.

Methylmercury analysis is not a routine analytical procedure. Accordingly, we suggest that mercury monitoring continue to be done on the basis of analysis of an unfiltered sample preserved with acid dichromate, with the results being compared with the limits for inorganic mercury in the case of the "safe" and "acute" levels, and with the methylmercury limit in the case of the "swimmers" level. It is expected that most of the mercury reported as total soluble mercury will be inorganic mercury but there are no data from the Saint John River to confirm this hypothesis.

Only IWD method No. 80314 can achieve sufficient sensitivity to measure the "safe" level. EPA method No. 245.1 or 245.2 has a detection limit of 0.0002 mg/L. Samples collected for mercury analysis should be preserved in all-glass containers with dichromic acid. Using the NAQUADAT method the uncertainty of analysis at the "safe" level is $\pm$ 50%. Median values over 0.00013 mg/L should thus be considered beyond the objective.

Data sets can be compared to the "safe" and "swimmers" levels on the basis of one or more year's data, and on an individual basis with the "acute" level. If the total soluble mercury concentration exceeds one of these limits, an attempt must be made to ascertain the proportion of methylmercury in a subsequent sampling procedure. Short term concentrations of inorganic mercury between 0.0032 mg/L and 0.038 mg/L should not result in the death of fish but would cause mortality among aquatic invertebrates. The "safe" limits for methylmercury and for inorganic mercury are based on the concentrations at which continuous exposure would lead to the accumulation of 0.5 ug/g in the flesh of fish. No important adverse effects on the fish themselves should occur below 0.000078 mg/L methylmercury or about 0.0002 mg/L inorganic mercury.

Historical mercury data indicate that fish should be accumulating mercury to beyond the 0.5 ug/g level at several sampling sites. Historical levels have occasionally been high enough to have sublethal effects on fish." (Int. Techn. Adv. Comm., 1980).

Key Aspects

- "fishable-swimmable" use protection
- two levels of safety for aquatic life
- instantaneous (grab sample) and long term (seasonal, annual averages) monitoring data are evaluated against the toxicity-based objectives.

2.11 OTHERS

United States

The 1972 Federal Water Pollution Control Act declares that state and public policy is to maintain or improve, or both, standards of quality and priority of the waters of each state. To this end, the United States Environmental Protection Agency encourages cooperative work with each state to establish water quality standards (similar to CCREM objectives) for each waterbody.

A water quality survey is carried out to identify problems, characterize uses and determine if and why uses are improved or precluded. Streams or stream segments are then classified, on the basis of ecosystems, and designated uses are assigned according to the quality of ecosystems components. Site specific criteria are developed by taking local water quality conditions into account so that EPA's laboratory-derived criteria are adequate to protect designated uses without being more stringent than needed. After the site specific criteria are developed, the water quality standard is formulated. Public hearings are held prior to extablishment of criteria and standards and thier revision. By consulting with EPA throughout the establishment and review process, states can be assured that EPA will expeditiously review submissions and determine that the standards meet the requirements of the Act (EPA, 1982).

United States Enviromental Protection Agency

The United States Environmental Protection Agency (EPA) has outlined procedures for the development of water quality criteria which reflect local environmental conditions. The site-specific criteria (guidelines) may be utilized as a basis for establishing standards (objectives) to protect the uses of a water body. The development of standards (objectives) should take into account additonal factors such as the use of the site, social, legal and economic considerations, water chemistry and biology of the water body (USEPA, 1982).

The procedures are:

1. The recalculation procedure. This accounts for differences between the sensitivity of the resident species to the chemical of interest and existing criteria.

2. The indicator species procedure. This is used when the resident species range of sensitivity is similar to that for species used for

existing criteria, and the possibility exists that water quality characteristics may affect the bioavailability and therefore toxicity, of the chemical of interest.

3. The resident species procedure. This accounts for differences in the bioavailability and therefore toxicity, of a chemical due to water quality variability.

4. The heavy metal speciation procedure. This allows for the comparison of ambient soluble or biologically available metal concentrations to existing criteria, if there is a possibility that significant portions of ambient metal concentrations are present in biologically unavailable forms with sediments (USEPA, 1982).

Australia

Australia has derived water quality criteria (similar to CCREM guidelines) for the protection of domestic water supplies, aquatic ecosystems, agricultural water use, industrial water use and aesthetic uses. The criteria apply country-wide. Formulation of the criteria involves the establishment of exposure-effect relationships, and the use of these relationships to estimate 'safe' exposure limits. Some of the criteria have been formulated using Australian data and are therefore known to be appropriate for the Austrialian environment. Other criteria are based on foreign (i.e., U.S. EPA) data and are modified to suit the local environment. The latter are in temporary use until Australian work can be carried out (Hart, 1974).

European Inland Fisheries Advisory Commission

The European Inland Fisheries Advisory Commission (EIFAC), an intergovernmental organization of 24 countries, establishes water quality criteria (similar to CCREM guidelines) for European freshwater fish. It was recognized that quality of water for each use was needed to determine

the degree of pollution-control necessary and to estimate the effects of new or augmented discharges. Water quality standards for drinking water are well defined by the World Health Organization and standards exist for agricultural and industrial uses. Criteria for fish had not been adequately addressed. The Commission formed criteria for fish by examination of the literature, possible experimentation to fill in data gaps, and recommendations of desirable requirements for various aquatic organisms or groups of aquatic organisms with respect to the various qualities of water (Alabaster and Lloyd, 1981).

To date, EIFAC has recommended criteria for inland fisheries for water temperature, pH, dissolved oxygen, ammonia, phenols, copper, zinc, mercury, chlorine, and cadmium. The criteria are updated on an ongoing basis.

3.0 SUMMARY

Characteristics of the reviewed objectives development methodologies are tabulated in Table 1. The table is a qualitative summary of the methods and is not intended to rate the methods. Rating the methods by the characteristics is impossible due to the varying importance of each characteristic for each water quality variable. The characteristic "effort" was added to subjectively represent the relative amount of work involved in objective development by each method.

Choice of any method or combination of methods requires detailed consideration of factors including significant variables, information available, intended purpose of the objectives and commitment of agencies.

Table 1. Characteristics of Various Objectives Development Methodologies

Characteristics	British Columbia	Manitoba	Prairie Provinces Water Board	Alberta, Saskatchewan	Poplar - most - TDS, B.	Red - alert - objectives	Ontario - provinces	Ottawa	Great Lakes	St. John River
Issue-based	Y	-	N	N	N Y	- Y	N	N	Y	-
Development of site/basin-specific criteria	Y	N	N	N	N N	N N	N	N	N	N
Site/basin-specific objectives	Y	N	Y	N	Y Y	Y N	N	N	Y	Y
Use-specific objectives	Y	Y	Y	N	Y Y	Y N	N	N	N	Y
Protection of most sensitive use	Y	Y	Y	N	Y Y	Y Y	Y	N	Y	Y
Protection of all species, all life stages	Y	N	-	N	Y	Y Y	Y	N	Y	Y
Protection of ecosystem	N	N	N	N	N N	N N	N	N	Y	N
Protection - short term	Y	Y	Y	Y	Y Y	Y Y	Y	-	Y	Y
Protection - long term	Y	N	Y	N	N Y	N N	N	N	Y	Y
Use of acute, chronic data	Y	Y	N	Y	Y N	Y Y	Y	Y	Y	Y
Use of site/basin-specific water quality data	Y	Y	Y	-	N Y	- -	N	-	Y	Y
Field validation of objectives	N	N	N	N	N N	N N	N	N	Y	N
Monitoring program for objectives	Y	N	Y	Y	Y Y	Y Y	N	Y	Y	Y
Mandatory review period	N	N	N	N	N Y	Y -	N	N	Y	-
Flexibility (ease of change of objectives)	Y	N	N	N	N N	Y N	N	Y	Y	Y
Legally enforceable	N	N	N	N	N N	N N	N	N	N	N
Account for Seasonality	N	N	Y	N	N Y	N N	N	N	Y	Y
Effort	-	-	-	N	- Y	- Y	N	N	Y	-

Y = yes; N = no; - = maybe, sometimes

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